

CHLOROFORM

Identified as a toxic air contaminant under California's air toxics program (AB 1807) in 1990.

CAS Registry Number: 67-66-3

CHCl_3

Molecular Formula: CHCl_3

Chloroform is a clear colorless volatile liquid with an ethereal scent that is nonflammable and does not form explosive mixtures at atmospheric temperatures and pressures. It is miscible with most organic solvents, and is slightly soluble in water. Chloroform evaporates quickly and in its concentrated gaseous form, it will tend to settle to the ground before dispersing. Chloroform can be manufactured, or can occur naturally when a chlorine molecule (Cl_2) reacts with an organic substance such as humic or fulvic acids. Chloroform vapor does not react with oxygen at temperatures up to 290 °C. However, at 270 °C, nitrogen dioxide oxidizes chloroform to form phosgene, hydrogen chloride, water, and carbon dioxide. Pyrolysis of chloroform vapor occurs at temperatures above 450 °C, producing tetrachloroethylene, hydrogen chloride, and minor amounts of other chlorocarbons. Chloroform can be further chlorinated to carbon tetrachloride by elemental chlorine upon irradiation of the vapor. At 225 °C to 275 °C, bromination of chloroform vapor yields bromochloromethanes (ARB, 1990a). Liquid chloroform will attack some forms of plastics, rubber, and coatings (HSDB, 1995; Merck, 1989).

Physical Properties of Chloroform

Synonyms: trichlormethane; methane trichloride; methenyl chloride; trichloroform; TCM; methyl trichloride; methenyl trichloride

Molecular Weight:	119.38
Boiling Point:	61 - 62 °C
Melting Point:	-63.5 °C
Vapor Pressure:	159 mm Hg at 20 °C
Density/Specific Gravity:	1.498 at 15 °C
Vapor Density:	4.12
Log Octanol/Water Partition Coefficient:	1.97
Conversion Factor:	1 ppm = 4.88 mg/m ³

(HSDB, 1995; Merck, 1989; Sax, 1989; U.S. EPA, 1994a)

SOURCES AND EMISSIONS

A. Sources

Chloroform is used to produce fluorocarbon-22, oxybisphenoxarsine, 1,3-diisocyanate, and pharmaceuticals. Chloroform can be formed as a by-product of chlorinated water in swimming pools, tap water, cooling towers, and air stripping towers (ARB, 1990). More chloroform can be produced in drinking water during the summer than in the winter where drinking water is often dispersed and aerated, speeding the evaporation of chloroform (GCA, 1984). Chloroform may evaporate from tap water while showering with estimated concentrations ranging from 0.02 to 0.05 ppb. Chloroform is also formed by the aqueous reaction of chlorine with organic matter in the cooling water (ARB, 1990a).

Chloroform can also be produced when substances containing chlorine are added to the process waters used to bleach wood pulp. Chloroform is formed from the aqueous reaction of chlorine with organic substances in the wood pulp and then can be released to the air during the bleaching process and when effluents are released to receiving waters (ARB, 1990a).

The primary stationary sources that have reported emissions of chloroform in California are pulp mills, sanitary services, and paper mills (ARB, 1997b).

Chloroform was registered for use as a pesticide; however as of November 2, 1982, it is no longer registered for pesticidal use in California (DPR, 1996).

B. Emissions

The total emissions of chloroform from stationary sources in California to be at least 130,000 pounds per year, based on data reported under the Air Toxics "Hot Spots" Program (AB 2588) (ARB, 1997b).

C. Natural Occurrence

Chloroform may be a plant volatile (HSDB, 1995).

AMBIENT CONCENTRATIONS

Chloroform is routinely monitored by the statewide Air Resources Board (ARB) toxics monitoring network. The network's mean concentration of chloroform from January 1996 through December 1996 is estimated to be 0.176 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) or 0.036 parts per billion (ppb) (ARB, 1997b). When chloroform was formally identified as a toxic air contaminant, the population-weighted mean chloroform concentration was estimated

to be $0.15 \mu\text{g}/\text{m}^3$ or 0.03 ppb (ARB, 1990a).

The United States Environmental Protection Agency (U.S. EPA) estimated a mean concentration of $2.68 \mu\text{g}/\text{m}^3$ or 0.55 ppb from 104 urban and suburban locations throughout the country. They also measured chloroform in Columbus, Ohio, and 11 United States cities where mean concentrations were $0.16 \mu\text{g}/\text{m}^3$ or 0.03 ppb and $0.55 \mu\text{g}/\text{m}^3$ or 0.11 ppb with an overall mean of $0.4 \mu\text{g}/\text{m}^3$ or 0.08 ppb (U.S. EPA, 1993a).

INDOOR SOURCES AND CONCENTRATIONS

Exposure to chloroform in indoor air provides a significant proportion of the total daily exposure. Chloroform is released into indoor air by vaporization from chlorinated tap water, and chlorinated pools and spas. Chloroform can be emitted as an indirect byproduct during use of products containing other chlorinated compounds. For example, this can occur when consumer products containing chlorine are used for various bleaching or sanitization purposes (clothes washing, toilet bowl sanitization, etc.). It is also used as a solvent in the manufacture of products commonly found in homes or offices (ARB, 1990a).

During June 1990, volatile organic chemicals were measured by the ARB in 128 households in Woodland, California. The average indoor concentration of chloroform was below the limit of detection ($1.2 \mu\text{g}/\text{m}^3$) (Sheldon et al., 1992). In that study, the 90th percentile indoor concentration value was $2.7 \mu\text{g}/\text{m}^3$. The ARB estimates the indoor inhalation exposure to chloroform, based on median personal air exposure, to range from 0.6 to 30 micrograms per day and that upper exposures could range from 50 to 104 micrograms per day through drinking chlorinated drinking water (ARB, 1990a).

In another study, indoor levels of chloroform were observed to rise significantly in association with household use of hot water. During periods when hot water was used intensively, indoor air levels rose to an average of $31 \mu\text{g}/\text{m}^3$ but were negligible during periods of limited hot water use (Wallace et al., 1989).

Exposure data for the indoor household environment also comes from the Total Exposure Assessment Methodology (TEAM) studies conducted by the U.S. EPA in California during 1984 and 1987. Chloroform was found at higher levels in indoor air than outdoor air in both TEAM studies. The range of medians for chloroform in the outside air was 0.03 to $0.65 \mu\text{g}/\text{m}^3$. The range of medians for chloroform measured from fixed-site samplers in the inside air was higher at 0.56 to $1.11 \mu\text{g}/\text{m}^3$. In overnight personal air samples the median range was 0.03 to $1.50 \mu\text{g}/\text{m}^3$, also higher than outdoor air (Pellizzari et al., 1987b; 1989).

ATMOSPHERIC PERSISTENCE

Chloroform exists in the atmosphere in the gas phase. The dominant atmospheric loss process for chloroform is by the reaction with the hydroxyl radical. Based on this reaction, the atmospheric half-life and lifetime of chloroform is estimated to be 3.2 months and 4.6 months, respectively (Atkinson, 1994). The product of this reaction is phosgene plus a chlorine atom, which reacts in the atmosphere to form hydrogen chloride (Atkinson, 1995).

AB 2588 RISK ASSESSMENT INFORMATION

The Office of Environmental Health Hazard Assessment reviews risk assessments submitted under the Air Toxics “Hot Spots” Program (AB 2588). Of the risk assessments reviewed as of April 1996, chloroform was the major contributor to the overall cancer risk in 9 of the approximately 550 risk assessments reporting a total cancer risk equal to or greater than 1 in 1 million and contributed to the total cancer risk in 86 of these risk assessments. Chloroform also was the major contributor to the overall cancer risk in 3 of the approximately 130 risk assessments reporting a total cancer risk equal to or greater than 10 in 1 million, and contributed to the total cancer risk in 31 of these risk assessments (OEHHA, 1996a).

For non-cancer health effects, chloroform contributed to the total hazard index in 9 of the approximately 89 risk assessments reporting a total chronic hazard index greater than 1, and presented an individual hazard index greater than 1 in 1 of these risk assessments (OEHHA, 1996b).

HEALTH EFFECTS

The probable routes of human exposure to chloroform are inhalation, and ingestion (ARB, 1990a).

Non-Cancer: The vapors are irritating to the eyes and respiratory tract. Chloroform is a central nervous system depressant. At high levels it can also produce cardiac arrhythmias by sensitization to adrenaline. Chronic inhalation exposure to chloroform can damage the liver. Although chloroform is no longer used in anesthesia, side effects of its use included changes in respiratory rate, gastrointestinal effects, dizziness, headache, nausea, vomiting, hepatotoxicity, and kidney damage (Olson, 1994; Howard, 1990).

A chronic non-cancer Reference Exposure Level (REL) of 35 $\mu\text{g}/\text{m}^3$ is listed for chloroform in the California Air Pollution Control Officers Association Air Toxics “Hot Spots” Program, Revised 1992 Risk Assessment Guidelines. The toxicological endpoints considered for chronic toxicity are the gastrointestinal system and liver (CAPCOA, 1993). The Reference Concentration (RfC) for chloroform is under review by the U.S. EPA. The oral Reference Dose (RfD) for chloroform is 0.01 milligrams per kilogram per day based on fatty cyst formation in the livers of dogs. The U.S. EPA estimates that consumption of this dose or less, over a lifetime, would not likely result in the occurrence of chronic non-cancer effects.

No information is available on adverse reproductive or developmental effects of exposure to chloroform in humans (U.S. EPA, 1994a). Chloroform is embryotoxic and fetotoxic in experimental animals when exposure occurs by the oral or inhalation routes. It interferes with the maintenance of pregnancy in rodents, and is associated with abnormal sperm production in mice (ARB, 1990a).

Cancer: No information is available regarding cancer in humans or animals after inhalation exposure to chloroform. Chloroform has been shown to be carcinogenic in animals after oral exposures resulting in kidney and liver tumors. The U.S. EPA has classified chloroform in Group B2: Probable human carcinogen, with a potency value of 2.3×10^{-5} (microgram per cubic meter)⁻¹. The U.S. EPA estimates that if an individual were to breathe air containing chloroform at $0.04 \mu\text{g}/\text{m}^3$, over a lifetime, that person would theoretically have no more than a 1 in 1 million increased chance of developing cancer (U.S. EPA, 1994a). The International Agency for Research on Cancer has classified chloroform in Group 2B: Possible carcinogen based on inadequate evidence in humans and sufficient evidence in animals (IARC, 1987a).

The State of California has determined under Proposition 65 and AB 1807 that chloroform is a carcinogen (CCR, 1996; ARB, 1990a). The inhalation potency factor that has been used as a basis for regulatory action in California is 5.3×10^{-6} (microgram per cubic meter)⁻¹ (OEHHA, 1994). In other words, the potential excess cancer risk for a person exposed over a lifetime to $1 \mu\text{g}/\text{m}^3$ is estimated to be no greater than 5.3 in 1 million. The oral potency factor that has been used as a basis for regulatory action in California is 3.1×10^{-2} (milligram per kilogram per day)⁻¹ (OEHHA, 1994).

